Vaisala Total Lightning

Overview of TL Quality Considerations for Merged Network/GLM Applications

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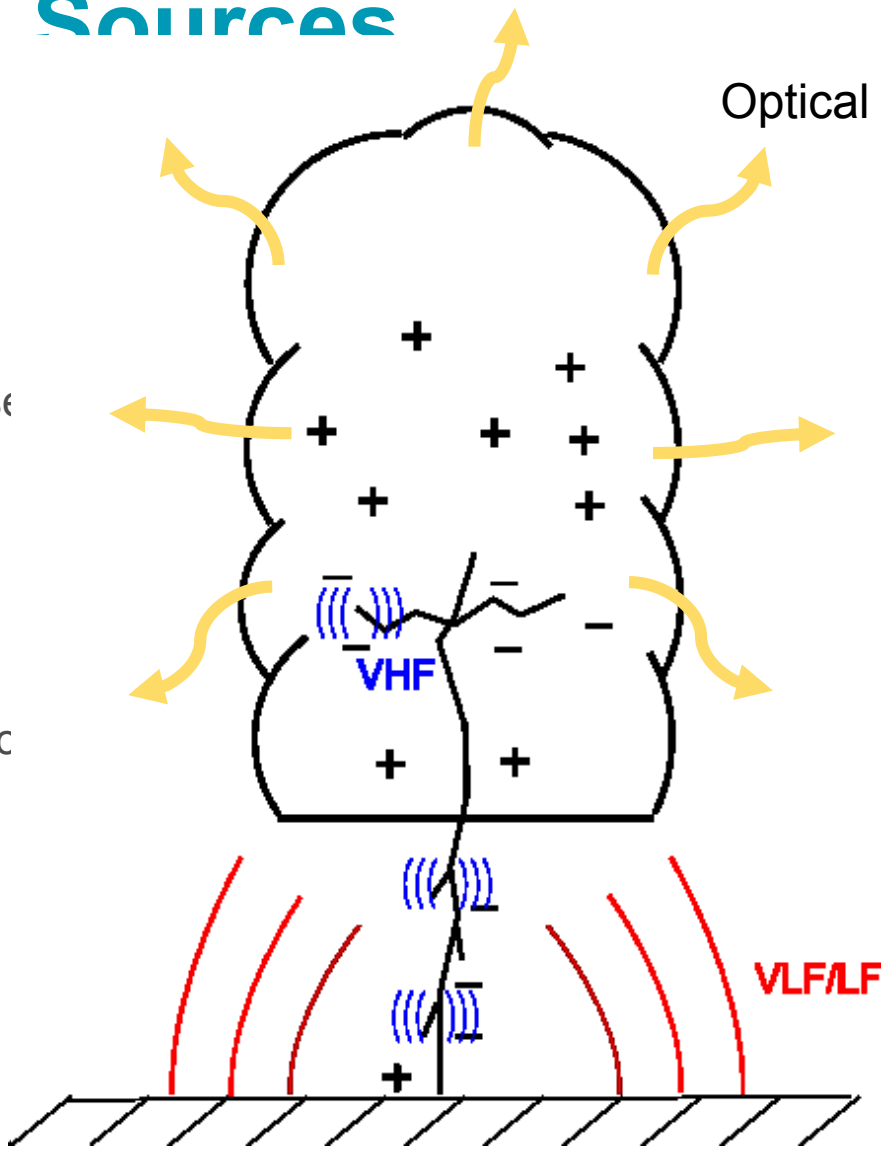
Feb 3, 2016

- Complementary Datasets
- Vaisala TL Technology

Lightning Radiation Sources

- Wavelength ~ feature size
- VHF (~30 – 300 MHz; 1–10 m)
  - Short branch channels/ breakdown processe
- LF (~30 – 300 kHz; 1 – 10 km)
  - Length of multi-km return-stroke channels
  - Long cloud pulses
- VLF (~3 – 30 kHz; 10 – 100 km)
  - Many complexities smoothed over in wavefc



Vaisala/GLM: Complementary Performance

LLS	DE		Median LA	Temporal Resolution	CG Peak Current Error	CG stroke Location, Multiplicity, Polarity	Classification Accuracy
	CG Flash	IC Flash					
NLDN TL	>95%	~60%	~200 m	< 1 μs	~15%	Yes	~90%
GLM	Total Flash DE 85-90%		~8 km	2 ms	NA	NA	NA

Complementary Information

Large-Area Network Data Strengths

- Spatial resolution
- CG strokes, IC pulses
- Event-level IC/CG classification
- Peak current, polarity
- Height*

Satellite Mapping Strengths

- Higher total lightning DE
- Mapping: flash extent, charge layer extent
- Optical intensity
- Larger geographic area
- Nominally uniform coverage

Merged Data: Supplementary

- Use network data to calibrate/monitor GLM performance
  - Uniform network DE is important (CG and IC)
  - Embedded network performance information in the data
    - error ellipse
    - number of sensors reporting
    - 5th percentile peak current
- Use GLM data to calibrate/monitor network performance
  - Reference TL flash count
- Mutual back-up
  - Calibrated continuous comparison between each data feed: flag transients in Network/Satellite performance

Merged Data: Complementary

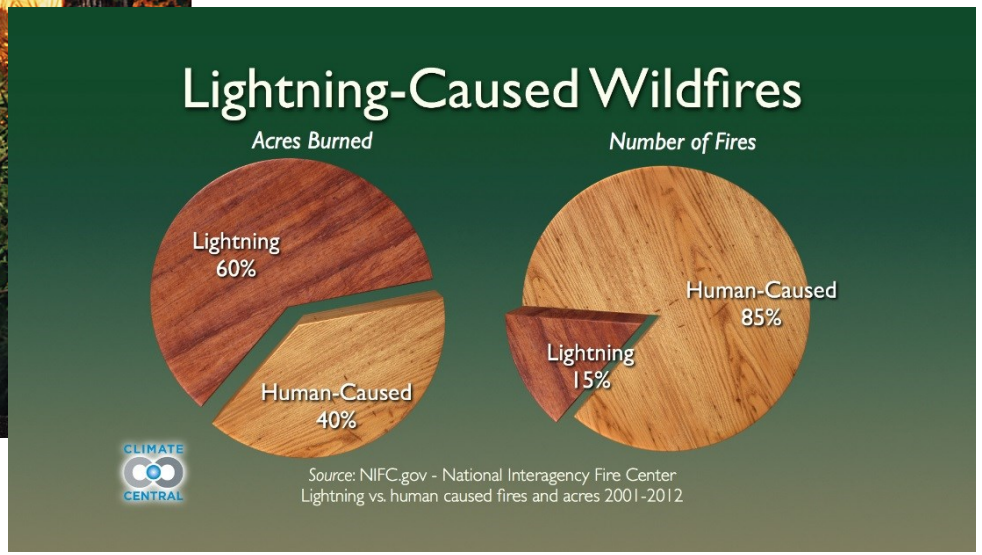
- Use network data to add temporal/spatial resolution to mapping data
- Network data provides CG attachment points with <200 m resolution and high-resolution IC pulse data
- Network data: Peak currents; GLM: optical intensity
- Use network classification and uniform, calibrated performance to monitor:
  - Individual flash types
  - Short time-averages of IC/CG ratio (eg severe storm monitoring/prediction)

Application Example

- Fire weather products
  - Combine resolution and peak current of network data with optical intensity (perhaps as continuing current proxy)

Photo by Liz Roll - May 31, 1998

http://www.fema.gov/media-library-data/4cb3001e-5908-404a-8785-e02bf911ee2f/3847_medium.jpg



Preliminary results relating lightning rate, type, and polarity to severe weather

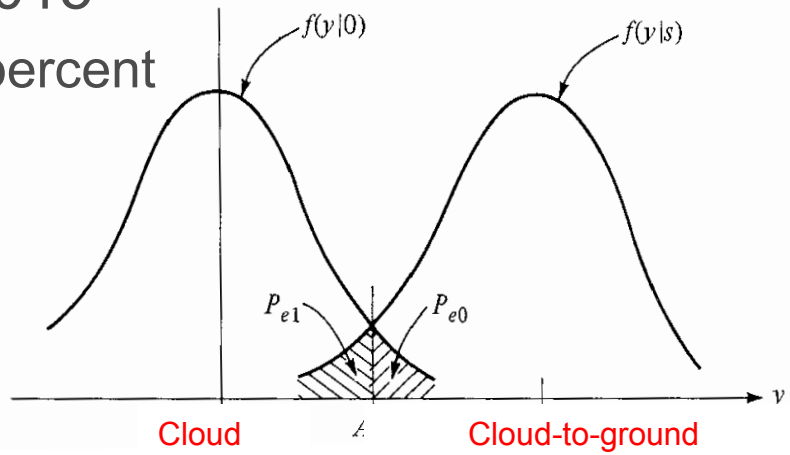
- Use Severe Storm Reports (SSRs) from SPC daily database
- Classified all storms by sounding type
- Check flash/source rates first (derivative in future work)
- Example: in most categories, tracking +IC flash rate is more skillful than total flash rate, which is better than tracking IC fraction

Critical Network Performance Characteristics

- Geographically/temporally stable performance
- IC/CG classification performance
- Spatial resolution
- Peak current accuracy

Vaisala TL: NLDN Summary

- Combined Time Of Arrival (TOA)/ Magnetic Detection Efficiency (MDF) sensor technology
- Significant upgrade in summer, 2013
  - Significant improvement in cloud flash DE. NLDN is a TL network
  - Maintain IC/CG classification performance, CG stroke accuracy
- Incremental upgrade in August, 2015
  - Increase cloud flash DE by a few percent
  - More cloud pulses/flash



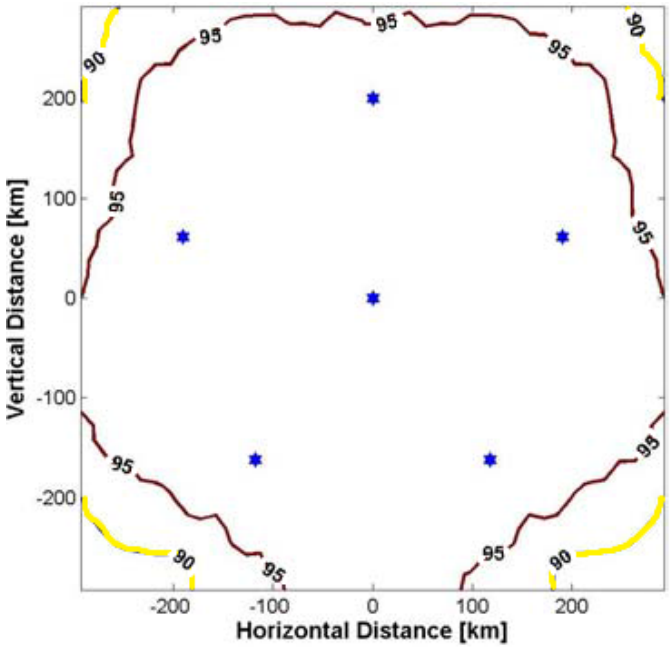
Advantage of Combined (TOA + MDF) vs TOA-only

- Combined technique: maximize DE with given number of sensors
- Helps maintain DE with sensor failures
- Provides more uniform performance with awkward sensor geometry

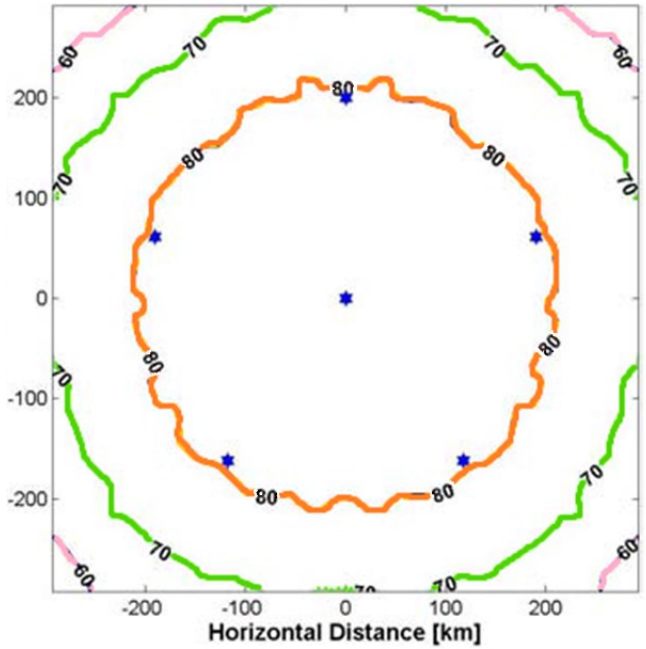
Advantage of combined MDF/TOA over TOA

- Combined MDF and TOA delivers significantly **better detection** than using TOA alone. Diendorfer demonstrates this with a 6 sensor network with 200 km baselines

MDF/TOA Network



TOA-only Network

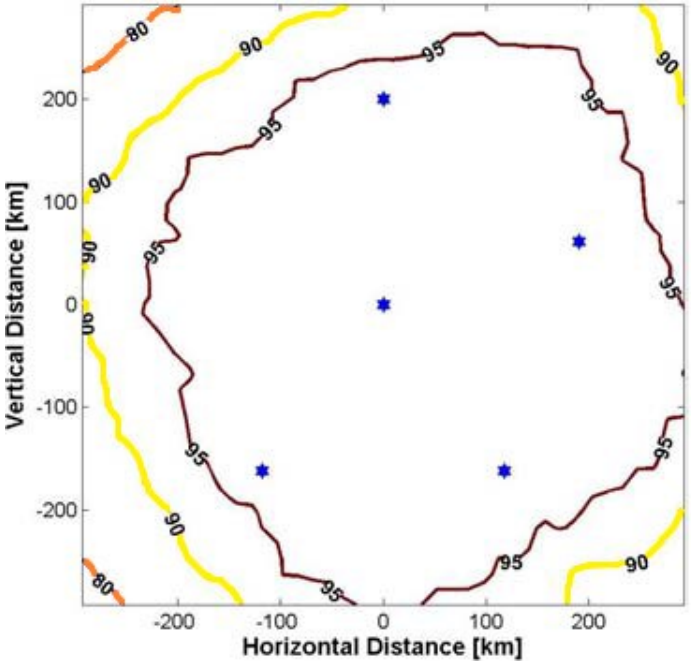


Diendorfer, G., (2007), "Lightning Location Systems," *IX International Symposium on Lightning Protection 26th-30th November 2007 – Foz do Iguaçu, Brazil*.

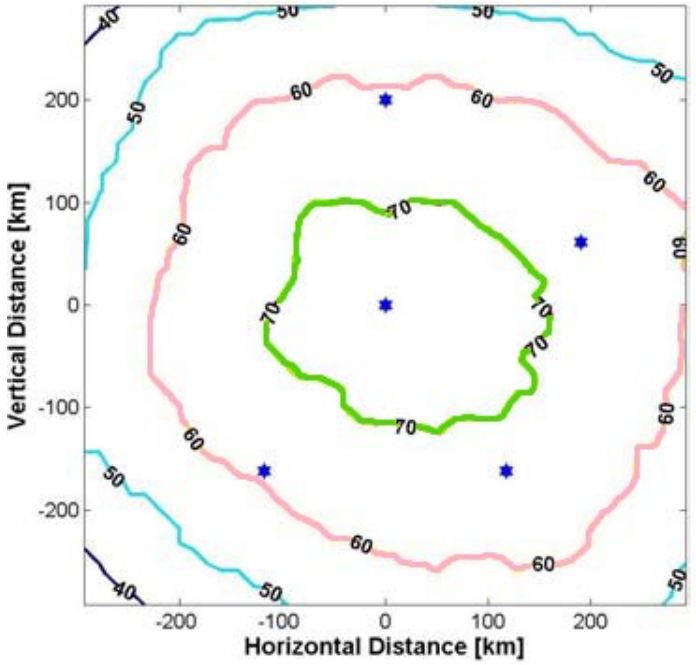
Advantage of combined MDF/TOA over TOA

- Detection Efficiency remains high if one of the 6 sensors goes down, demonstrating **excellent redundancy**

MDF/TOA Network



TOA-only Network



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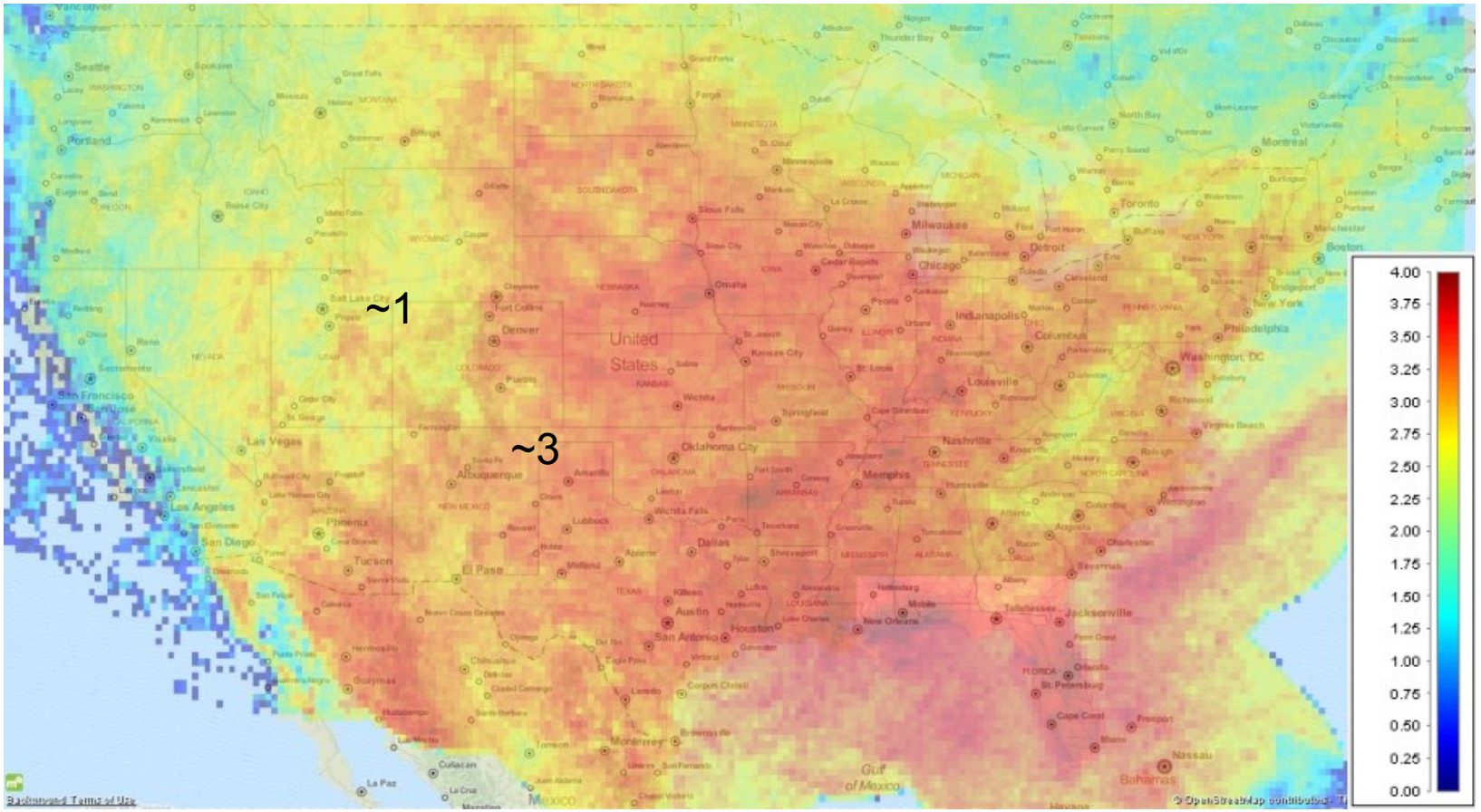
Validation Approaches

- Lightning climatology comparisons
- Inter-network comparisons
- Ground truth validation studies

2014 NLDN CG Flashes

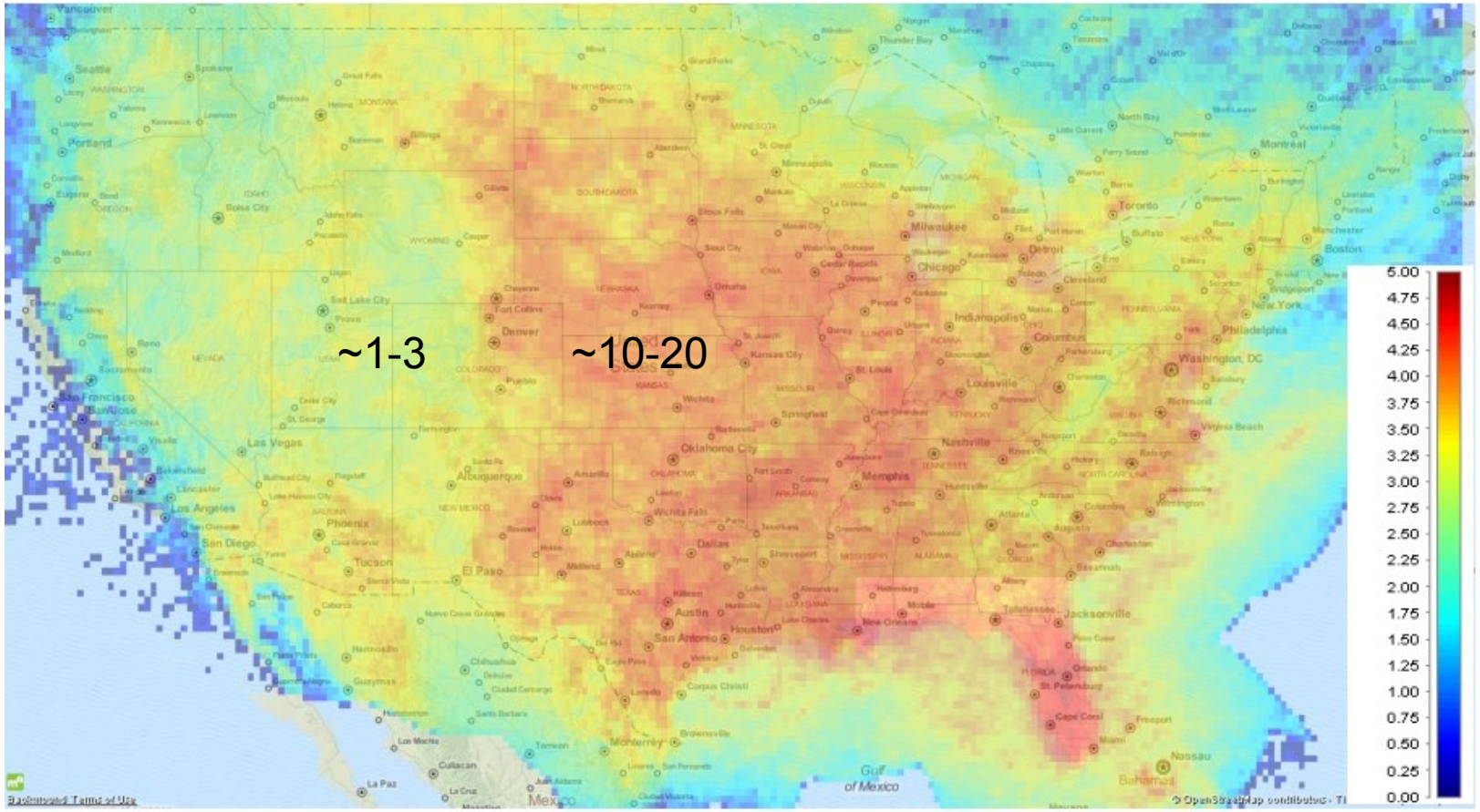
Annotation: fl / km^2 / yr

Murphy et al, 2015



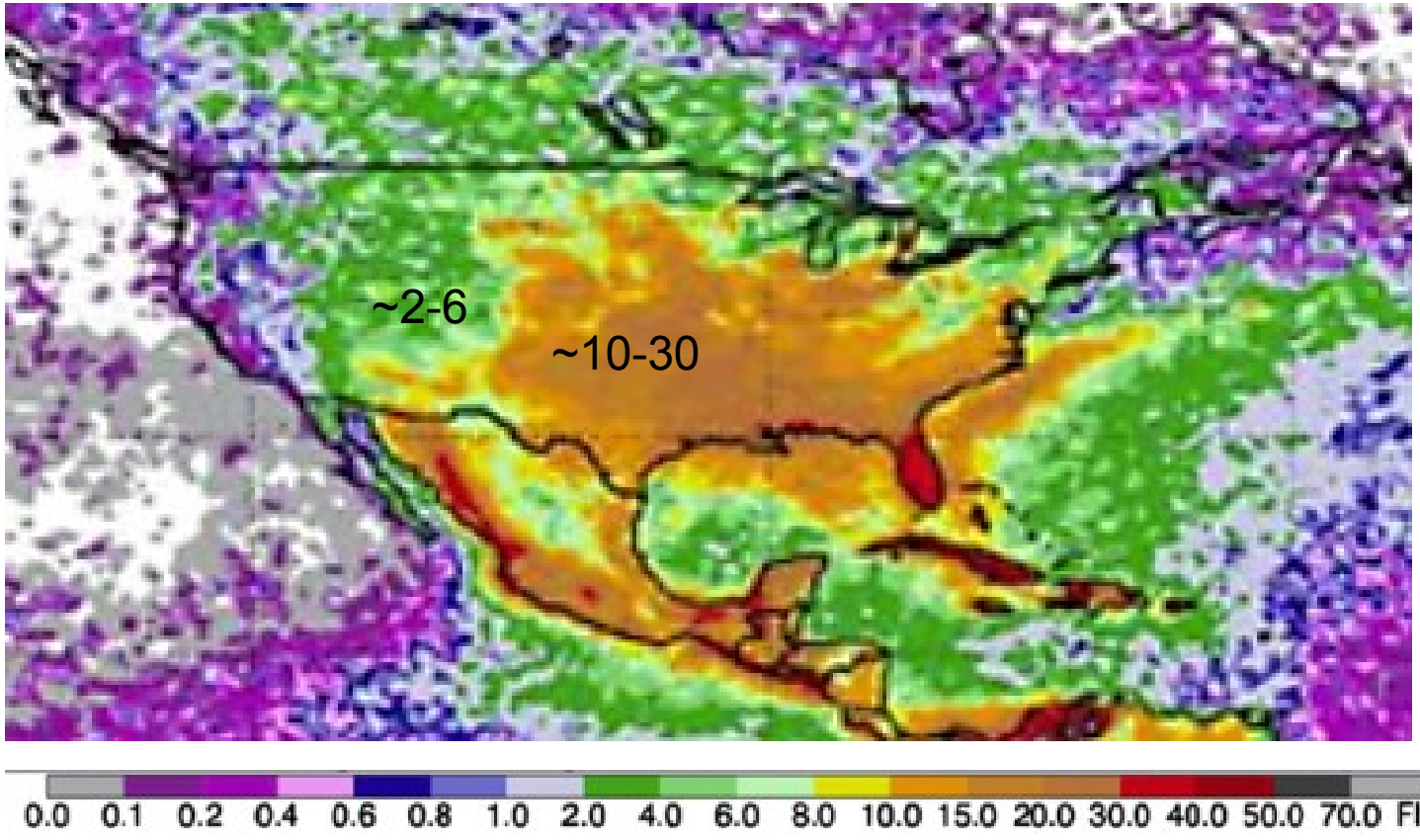
2014 NLDN IC Flashes

Murphy et al, 2015



Satellite (LIS, OTD)

Cecil et al, 2014



Rocket-Triggered Lightning Validation

Metric	NLDN[A]
Analysis Period	2013
Median Peak Current Error	15%
Percent misclassified events	3% (2004—2013)
Median Location Accuracy	173 m
Flash DE	100%

Mallick et al, 2014

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Other Ground Truth Studies

- LMA/Video Classification (Zhang et al, 2015)
  - >90% classification performance pre- and post-upgrade
- LMA cloud/total flash DE (Murphy et al 2015)
  - Oklahoma and Colorado LMA
  - 50—60% cloud flash DE

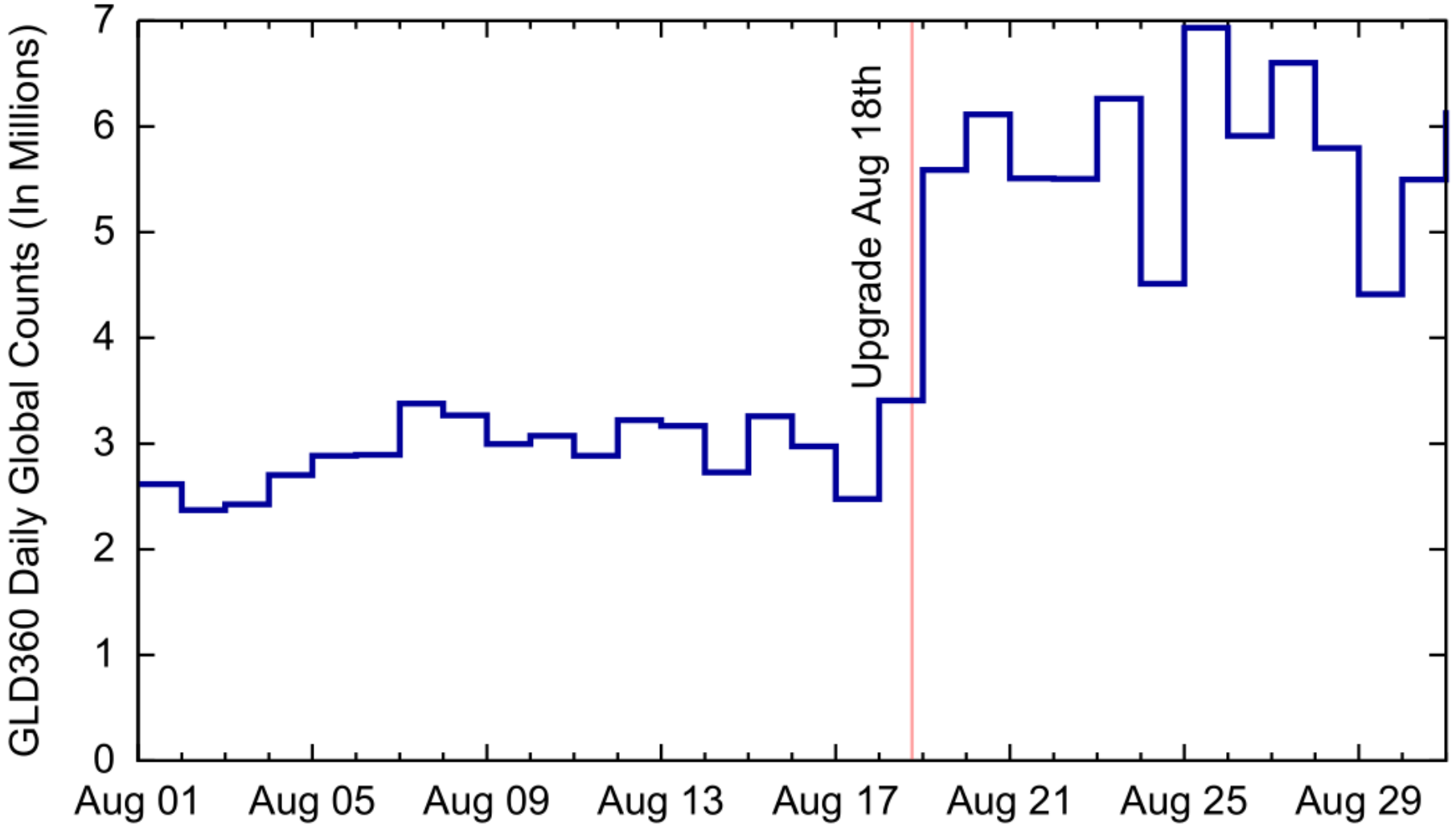
Summary

- NLDN dataset provides:
  - Stable performance
    - Upgrade in summer 2013 increased cloud DE to ~60%
    - Designed to provide spatially uniform performance
    - Technology (combined TOA/MDF) further improves stability
  - Well-validated performance
    - Ground truth validation studies
      - rocket-triggered lightning
      - LMA data/video records
    - Consistency with modeled performance
  - Consistent, accurate IC/CG classification
    - >90% classification performance pre- and post-2013 upgrade
    - Particularly important with upcoming GLM dataset

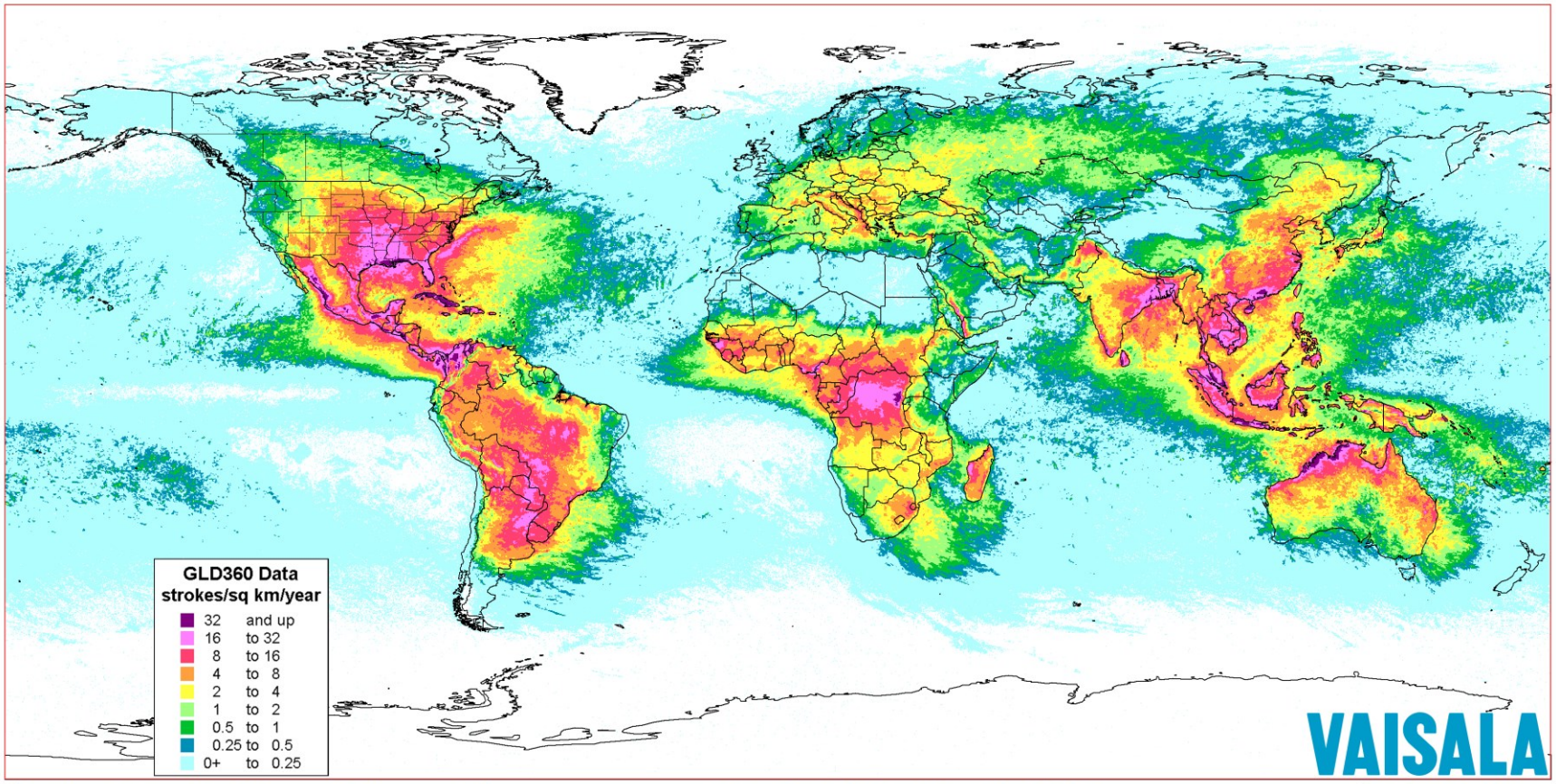
GLD360: Expanding TL to OCONUS

- Large sensor baselines (>1000 km)
- Uniform coverage over large areas
- VLF Sensor Network
- MDF + TOA
- B-field with Earth-ionosphere waveguide model: accurate Ip, future classification

GLD Counts: Upgrade released Aug 18



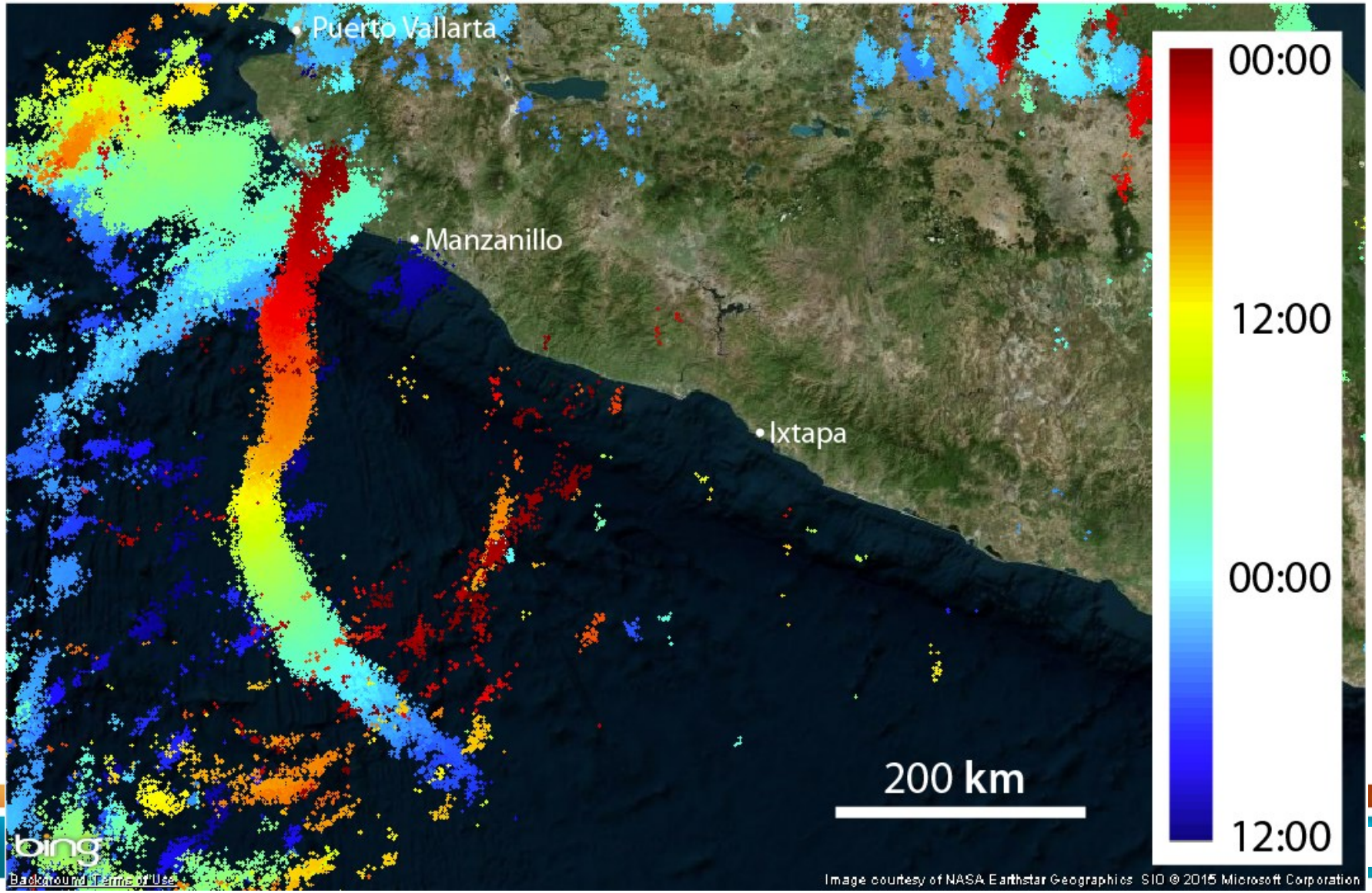
GLD360 Global lightning climatology: Stroke Density (4-year average)



Stroke Density Map - 20 km grid | May 6, 2011 - May 5, 2015 | GLD360 data

Hurricane Patricia
GLD360 Data
2015-Oct-22 12:00 UTC – 2015-Oct-24 00:00 UTC

VAISALA



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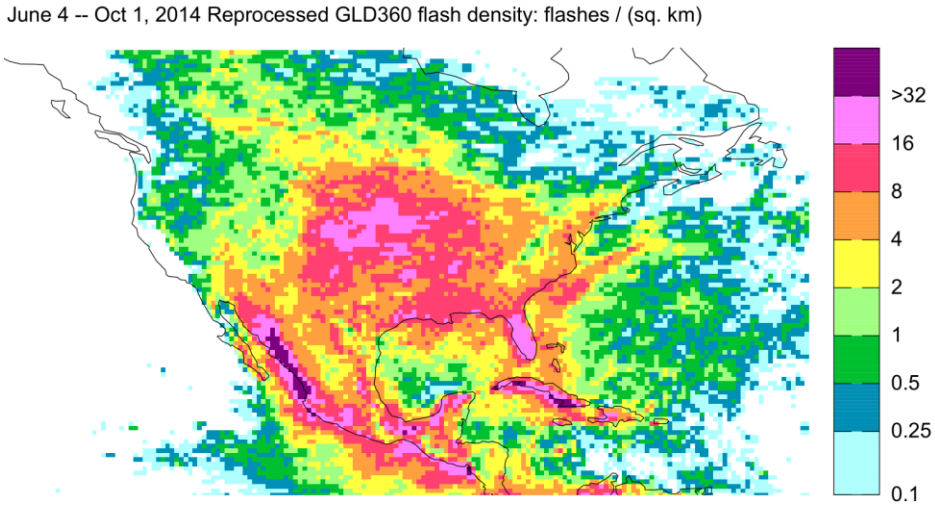
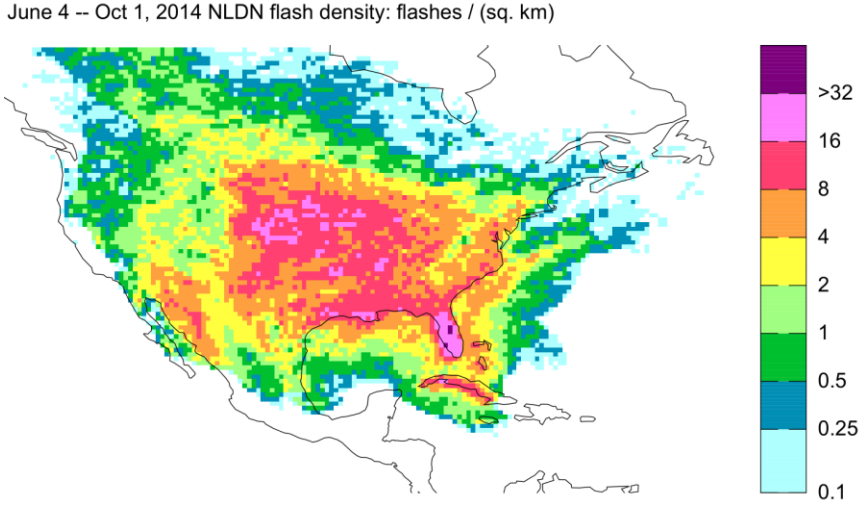
GLD360 Flash Density



NLDN Flash Density



Collaboration Work

- CRADA between Vaisala and NOAA (Steve Goodman)
  - Explore application examples and quality calibration using merged datasets
  - Upcoming Vaisala TL data into AWIPS
- AWC CRADA
  - Delivering real-time Vaisala TL, global GLD360
- MDL numerical convective forecast (Jess Charba)
  - 25 hour convection probability and potential
    - Increasing resolution to 1 hour, 10 km
  - TL data comparison
  - Future work: CG forecast

References

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